MCP9700/01

Low-Power Linear Active Thermistor™ ICs

Features

- Tiny Analog Temperature Sensor
- Available Packages: SC70-5
- Wide Temperature Measurement Range:
  - -40°C to +125°C
- Accuracy: ±4°C (max.), 0°C to +70°C
- Optimized for Analog-to-Digital Converters (ADCs):
  - **MCP9700:** 10.0 mV/°C (typ.)
  - **MCP9701:** 19.5 mV/°C (typ.)
- Wide Operating Voltage Range:
  - **MCP9700:** V_{DD} = 2.3V to 5.5V
  - **MCP9701:** V_{DD} = 3.1V to 5.5V
- Low Operating Current: 6 µA (typ.)
- Optimized to Drive Large Capacitive Loads

Typical Applications

- Hard Disk Drives and Other PC Peripherals
- Entertainment Systems
- Home Appliance
- Office Equipment
- Battery Packs and Portable Equipment
- General Purpose Temperature Monitoring

Description

The MCP9700/01 Linear Active Thermistor™ Intergrated Circuit (IC) is an analog temperature sensor that converts temperature to analog voltage. It's a low-cost, low-power sensor with an accuracy of ±4°C from 0°C to +70°C while consuming 6 µA (typ.) of operating current.

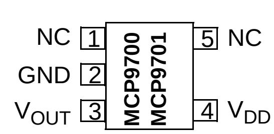
Unlike resistive sensors (such as thermistors), the Linear Active Thermistor IC does not require an additional signal-conditioning circuit. Therefore, the biasing circuit development overhead for thermistor solutions can be avoided by implementing this low-cost device. The voltage output pin (V_{OUT}) can be directly connected to the ADC input of a microcontroller. The MCP9700 and MCP9701 temperature coefficients are scaled to provide a 1 °C/bit resolution for an 8-bit ADC with a reference voltage of 2.5V and 5V, respectively.

The MCP9700/01 provides a low-cost solution for applications that require measurement of a relative change of temperature. When measuring relative change in temperature from +25°C, an accuracy of ±1°C (typ.) can be realized from 0°C to +70°C. This accuracy can also be achieved by applying system calibration at +25°C.

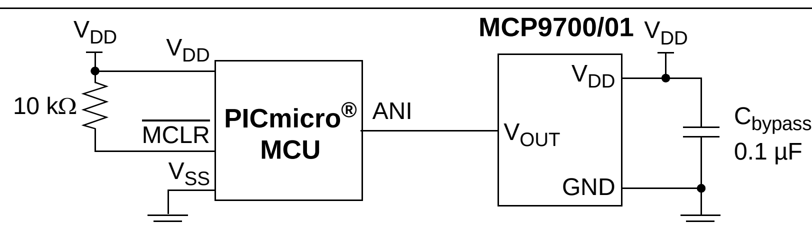
In addition, this family is immune to the effects of parasitic capacitance and can drive large capacitive loads. This provides Printed Circuit Board (PCB) layout design flexibility by enabling the device to be remotely located from the microcontroller. Adding some capacitance at the output also helps the output transient response by reducing overshoots or undershoots. However, capacitive load is not required for sensor output stability.

Package Type

SC70-5



Typical Application Circuit



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

V_{DD}:.. 6.0V

Storage temperature: .... -65°C to +150°C

Ambient Temp. with Power Applied:.. -40°C to +125°C

Junction Temperature (T_J):................................ 150°C

ESD Protection On All Pins (HBM:MM):.... (4 kV:200V)

Latch-Up Current at Each Pin: .... ±200 mA

†Notice: Stresses above those listed under “Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

DC ELECTRICAL CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated:
MCP9700: V_{DD} = 2.3V to 5.5V, GND = Ground, T_A = -40°C to +125°C and No load.
MCP9701: V_{DD} = 3.1V to 5.5V, GND = Ground, T_A = -10°C to +125°C and No load.

Parameter	Sym	Min	Typ	Max	Unit	Conditions
Power Supply						
Operating Voltage Range	V_{DD} V_{DD}	2.3 3.1	— —	5.5 5.5	V V	**MCP9700** **MCP9701**
Operating Current	I_{DD}	—	6	12	µA	
Power Supply Rejection Ratio	PSRR	—	0.1	—	°C/V	
Sensor Accuracy (Notes 1, 2)						
T_A = +25°C T_A = 0°C to +70°C T_A = -40°C to +125°C T_A = -10°C to +125°C	T_{ACY} T_{ACY} T_{ACY} T_{ACY}	— -4.0 -4.0 -4.0	±1 — — —	— +4.0 +6.0 +6.0	°C °C °C °C	 **MCP9700** **MCP9701**
Sensor Output						
Output Voltage: T_A = 0°C T_A = 0°C	 $V_{0°C}$ $V_{0°C}$	 — —	 500 400	 — —	 mV mV	 **MCP9700** **MCP9701**
Temperature Coefficient	T_{C1} T_{C1}	— —	10.0 19.5	— —	mV/°C mV/°C	**MCP9700** **MCP9701**
Output Non-linearity	V_{ONL}	—	±0.5	—	°C	T_A = 0°C to +70°C **(Note 2)**
Output Current	I_{OUT}	—	—	100	µA	
Output Impedance	Z_{OUT}	—	20	—	Ω	I_{OUT} = 100 µA, f = 500 Hz
Output Load Regulation	$\Delta V_{OUT}/$ ΔI_{OUT}	—	1	—	Ω	T_A = 0°C to +70°C, I_{OUT} = 100 µA
Turn-on Time	t_{ON}	—	800	—	µs	
Typical Load Capacitance (**Note 3**)	C_{LOAD}	—	—	1000	pF	
Thermal Response to 63%	t_{RES}	—	1.3	—	s	30°C (Air) to +125°C (Fluid Bath) (**Note 4**)

Note 1: The MCP9700 accuracy is tested with V_{DD} = 3.3V, while the MCP9701 accuracy is tested with V_{DD} = 5.0V.
2: The MCP9700/01 is characterized using the first-order or linear equation, as shown in Equation 4-2.
3: The MCP9700/01 family is characterized and production-tested with a capacitive load of 1000 pF.
4: Thermal response with 1x1 inch, dual-sided copper clad.

TEMPERATURE CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated:
MCP9700: V_{DD} = 2.3V to 5.5V, GND = Ground, T_A = -40°C to +125°C and No load.
MCP9701: V_{DD} = 3.1V to 5.5V, GND = Ground, T_A = -10°C to +125°C and No load.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Temperature Ranges						
Specified Temperature Range	T_A	-40	—	+125	°C	**MCP9700** (**Note**)
	T_A	-10	—	+125	°C	**MCP9701** (**Note**)
Operating Temperature Range	T_A	-40	—	+125	°C	
Storage Temperature Range	T_A	-65	—	+150	°C	
Thermal Package Resistances						
Thermal Resistance, 5L-SC70	θ_{JA}	—	331	—	°C/W	

Note: Operation in this range must not cause T_J to exceed Maximum Junction Temperature (+150°C).

2.0 TYPICAL PERFORMANCE CURVES

Note:	The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

Note: Unless otherwise indicated, **MCP9700**: V_{DD} = 2.3V to 5.5V; **MCP9701**: V_{DD} = 3.1V to 5.5V; GND = Ground, C_{bypass} = 0.1 µF.

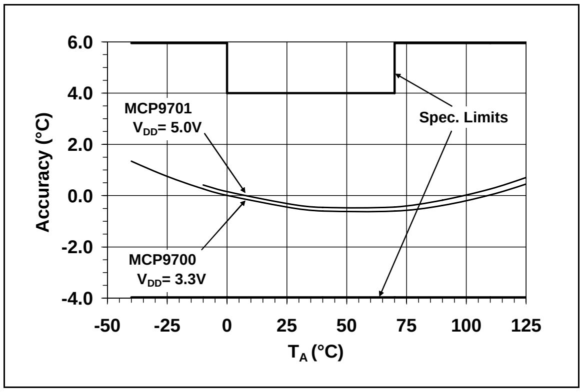


FIGURE 2-1: *Accuracy vs. Ambient Temperature.*

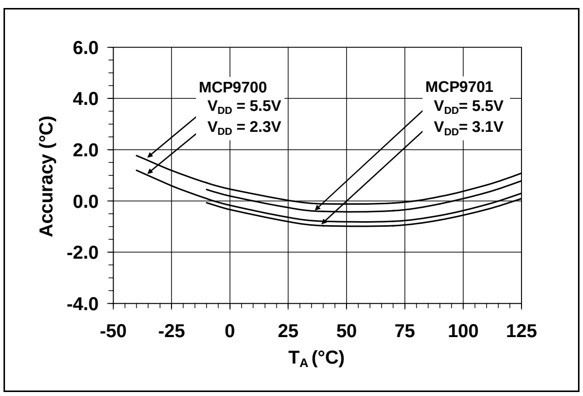


FIGURE 2-2: *Accuracy vs. Ambient Temperature, with V_{DD}.*

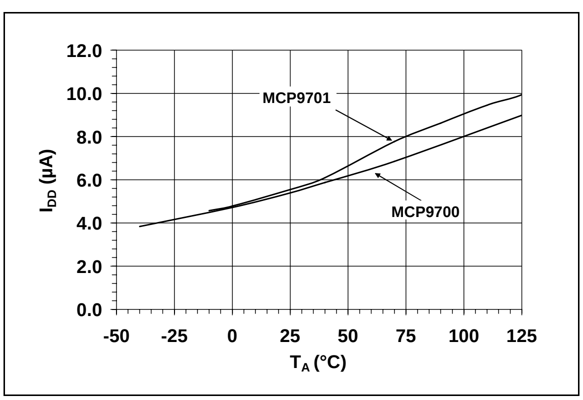


FIGURE 2-3: *Supply Current vs. Temperature.*

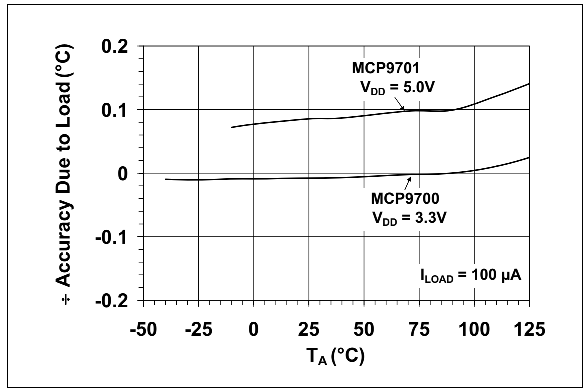


FIGURE 2-4: *Changes in Accuracy vs. Ambient Temperature (Due to Load).*

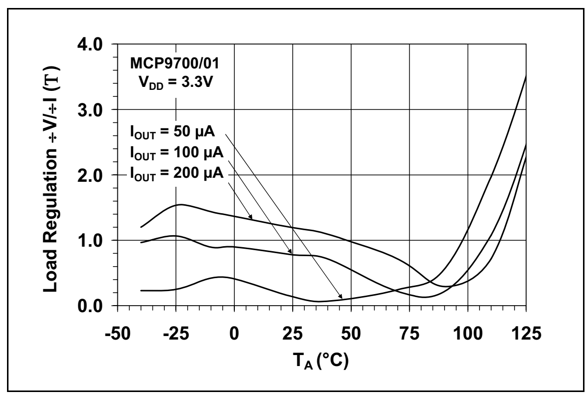


FIGURE 2-5: *Load Regulation vs. Ambient Temperature.*

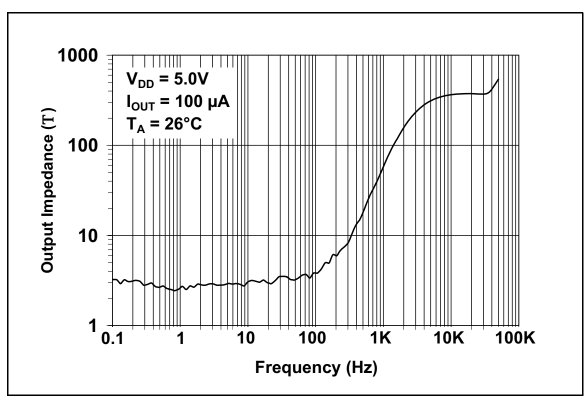


FIGURE 2-6: *Output Impedance vs. Frequency.*

Note: Unless otherwise indicated, **MCP9700**: V_{DD} = 2.3V to 5.5V; **MCP9701**: V_{DD} = 3.1V to 5.5V; GND = Ground, C_{bypass} = 0.1 µF.

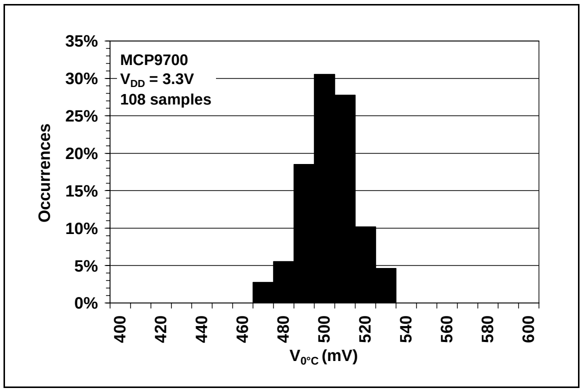


FIGURE 2-7: *Output Voltage at 0°C (MCP9700).*

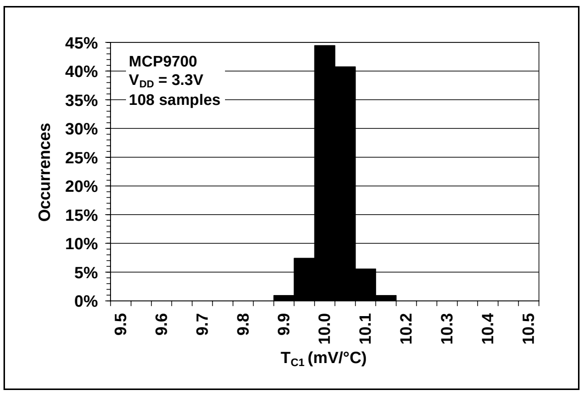


FIGURE 2-8: *Occurrences vs. Temperature Coefficient (MCP9700).*

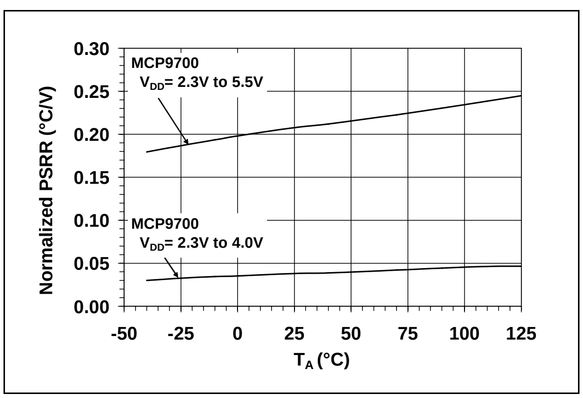


FIGURE 2-9: *Power Supply Rejection Ration (PSRR) vs. Ambient Temperature.*

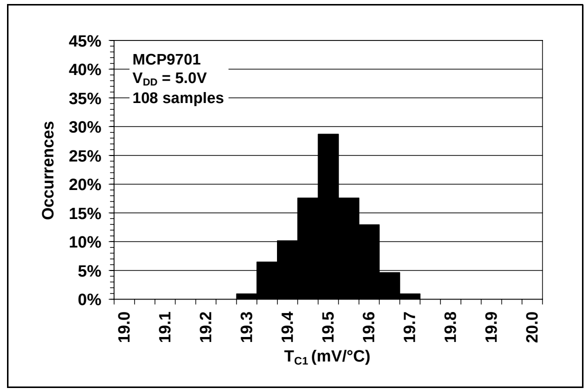


FIGURE 2-10: Output Voltage at 0°C (MCP9701).

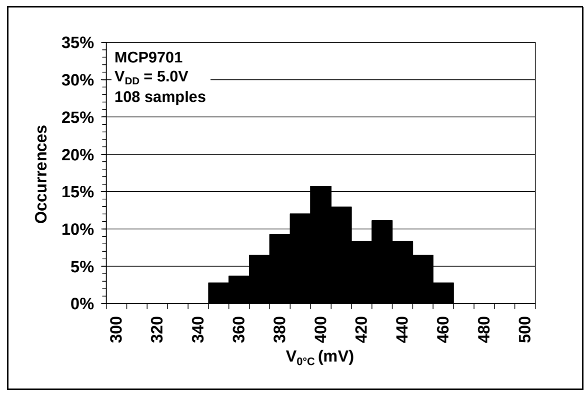


FIGURE 2-11: *Occurrences vs. Temperature Coefficient (MCP9701).*

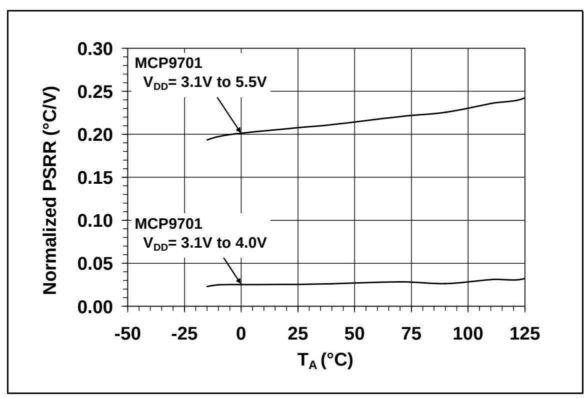


FIGURE 2-12: *Power Supply Rejection Ratio (PSRR) vs. Temperature.*

Note: Unless otherwise indicated, **MCP9700**: V_{DD} = 2.3V to 5.5V; **MCP9701**: V_{DD} = 3.1V to 5.5V; GND = Ground, C_{bypass} = 0.1 µF.

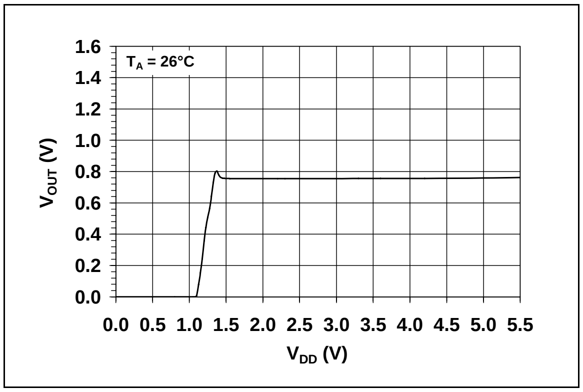


FIGURE 2-13: *Output Voltage vs. Power Supply.*

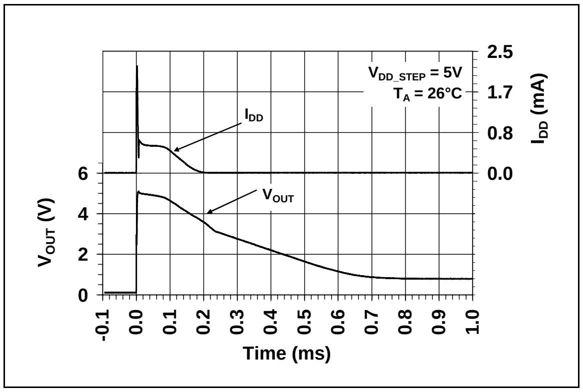


FIGURE 2-14: *Output vs. Settling Time to step V_{DD}.*

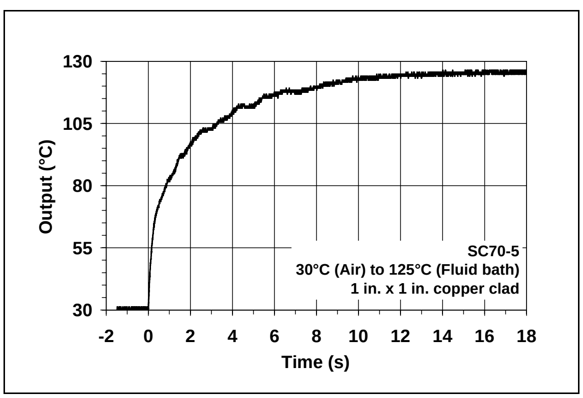


FIGURE 2-15: *Thermal Response.*

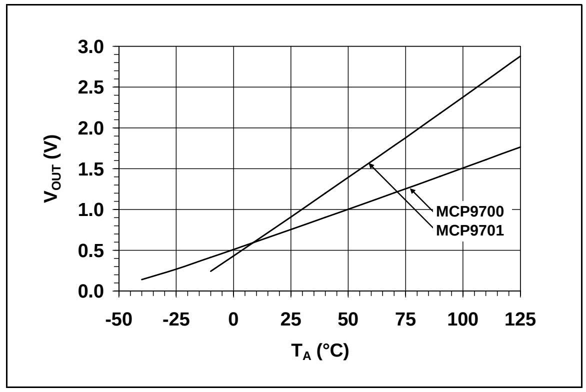


FIGURE 2-16: *Output Voltage vs. Ambient Temperature.*

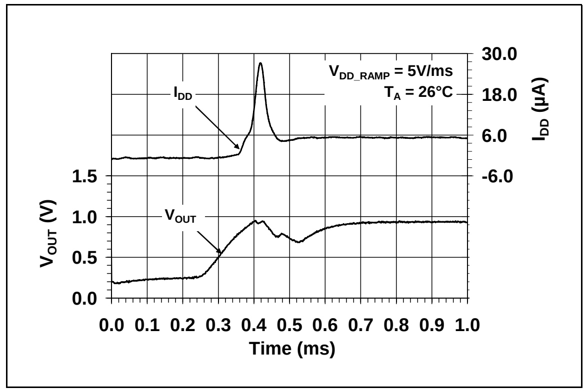


FIGURE 2-17: *Output vs. Settling Time to Ramp V_{DD}.*

3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in DC Electrical Characteristics.

TABLE 3-1: PIN FUNCTION TABLE

Pin No.	Name	Function
1	NC	No Connect
2	GND	Power Ground Pin
3	V_{OUT}	Output Voltage Pin
4	V_{DD}	Power Supply Input
5	NC	No Connect

3.1 Power Ground Pin (GND)

GND is the system ground pin.

3.2 Output Voltage Pin (V_{OUT})

The sensor output can be measured at V_{OUT}. The voltage range over the operating temperature range for the MCP9700 is 100 mV to 1.75V and for the MCP9701, 200 mV to 3V .

3.3 Power Supply Input (V_{DD})

The operating voltage as specified in the DC Electrical Characteristics table is applied to V_{DD}.

4.0 APPLICATIONS INFORMATION

The Linear Active Thermistor™ IC uses an internal diode to measure temperature. The diode electrical characteristics have a temperature coefficient that provides a change in voltage based on the relative ambient temperature from -40°C to 125°C. The change in voltage is scaled to a temperature coefficient of 10.0 mV/°C (typ.) for the MCP9700 and 19.5 mV/°C (typ.) for the MCP9701. The output voltage at 0°C is also scaled to 500 mV (typ.) and 400 mV (typ.) for the MCP9700 and MCP9701, respectively. This linear scale is described in the first-order transfer function shown in Equation 4-1.

EQUATION 4-1: SENSOR TRANSFER FUNCTION

$$V_{OUT} = T_{C1} \bullet T_A + V_{0°C}$$

Where:

T_A = Ambient Temperature
V_{OUT} = Sensor Output Voltage
$V_{0°C}$ = Sensor Output Voltage at 0°C
T_{C1} = Temperature Coefficient

4.1 Improving Accuracy

The MCP9700/01 accuracy can be improved by performing a system calibration at a specific temperature. For example, calibrating the system at +25°C ambient improves the measurement accuracy to a ±0.5°C (typ.) from 0°C to +70°C, as shown in Figure 4-1. Therefore, when measuring relative temperature change, this family measures temperature with higher accuracy.

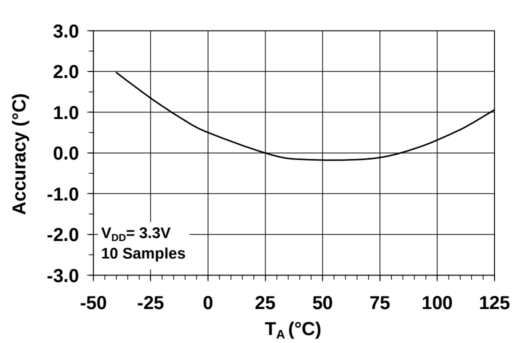


FIGURE 4-1: *Relative Accuracy to +25°C vs. Temperature.*

The change in accuracy from the calibration temperature is due to the output non-linearity from the first-order equation, as specified in Equation 4-2. The accuracy can be further improved by compensating for the output non-linearity.

For higher accuracy using a sensor compensation technique, refer to AN1001 *"IC Temperature Sensor Accuracy Compensation with a PICmicro® Microcontroller"* (DS01001). The application note shows that if the MCP9700 is compensated in addition to room temperature calibration, the sensor accuracy can be improved to ±0.5°C (typ.) accuracy over the operating temperature (Figure 4-2).

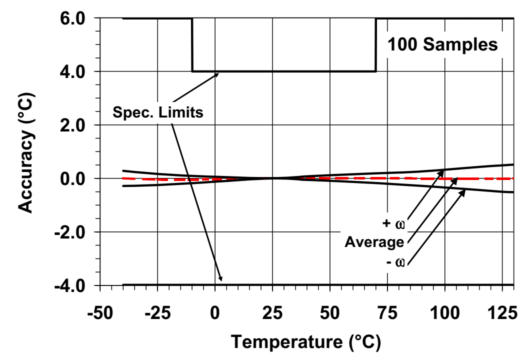


FIGURE 4-2: *MCP9700 Calibrated Sensor Accuracy.*

The compensation technique provides a linear temperature reading. A firmware look-up table can be generated to compensate for the sensor error.

4.2 Shutdown Using Microcontroller I/O Pin

The MCP9700/01 low operating current of 6 µA (typ.) makes it ideal for battery-powered applications. However, for applications that require tighter current budget, this device can be powered using a microcontroller Input/Output (I/O) pin. The I/O pin can be toggled to shut down the device. In such applications, the microcontroller internal digital switching noise is emitted to the MCP9700/01 as power supply noise. This switching noise compromises measurement accuracy. Therefore, a decoupling capacitor and series resistor will be necessary to filter out the system noise.

4.3 Layout Considerations

The MCP9700/01 does not require any additional components to operate. However, it is recommended that a decoupling capacitor of 0.1 µF to 1 µF be used between the V_{DD} and GND pins. In high-noise applications, connect the power supply voltage to the V_{DD} pin using a 200Ω resistor with a 1 µF decoupling capacitor. A high-frequency ceramic capacitor is recommended. It is necessary for the capacitor to be located as close as possible to the V_{DD} and GND pins in order to provide effective noise protection. In addition, avoid tracing digital lines in close proximity to the sensor.

4.4 Thermal Considerations

The MCP9700/01 measures temperature by monitoring the voltage of a diode located in the die. A low-impedance thermal path between the die and the PCB is provided by the pins. Therefore, the MCP9700/01 effectively monitors the temperature of the PCB. However, the thermal path for the ambient air is not as efficient because the plastic device package functions as a thermal insulator from the die. This limitation applies to plastic-packaged silicon temperature sensors. If the application requires measuring ambient air, the PCB needs to be designed with proper thermal conduction to the sensor pins.

The MCP9700/01 is designed to source/sink 100 µA (max.). The power dissipation due to the output current is relatively insignificant. The effect of the output current can be described using Equation 5-1.

EQUATION 4-2: EFFECT OF SELF-HEATING

$$T_J - T_A = \theta_{JA}(V_{DD}I_{DD} + (V_{DD} - V_{OUT})I_{OUT})$$

Where:

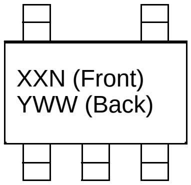
T_J	=	Junction Temperature
T_A	=	Ambient Temperature
θ_{JA}	=	Package Thermal Resistance (331°C/W)
V_{OUT}	=	Sensor Output Voltage
I_{OUT}	=	Sensor Output Current
I_{DD}	=	Operating Current
V_{DD}	=	Operating Voltage

At T_A = +25°C (V_{OUT} = 0.75V) and maximum specification of I_{DD} = 12 µA, V_{DD} = 5.5V and I_{OUT} = +100 µA, the self-heating due to power dissipation (T_J – T_A) is 0.179°C.

5.0 PACKAGING INFORMATION

5.1 Package Marking Information

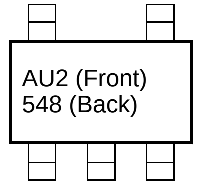
5-Lead SC-70 (**MCP9700**)



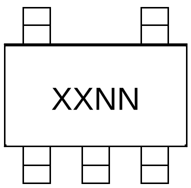
Device	Code
MCP9700	AUN
MCP9701	AVN

Note: Applies to 5-Lead SC-70.

Example:



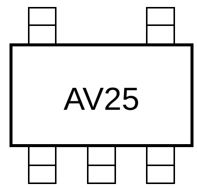
5-Lead SC-70 (**MCP9701**)



Device	Code
MCP9700	AUNN
MCP9701	AVNN

Note: Applies to 5-Lead SC-70.

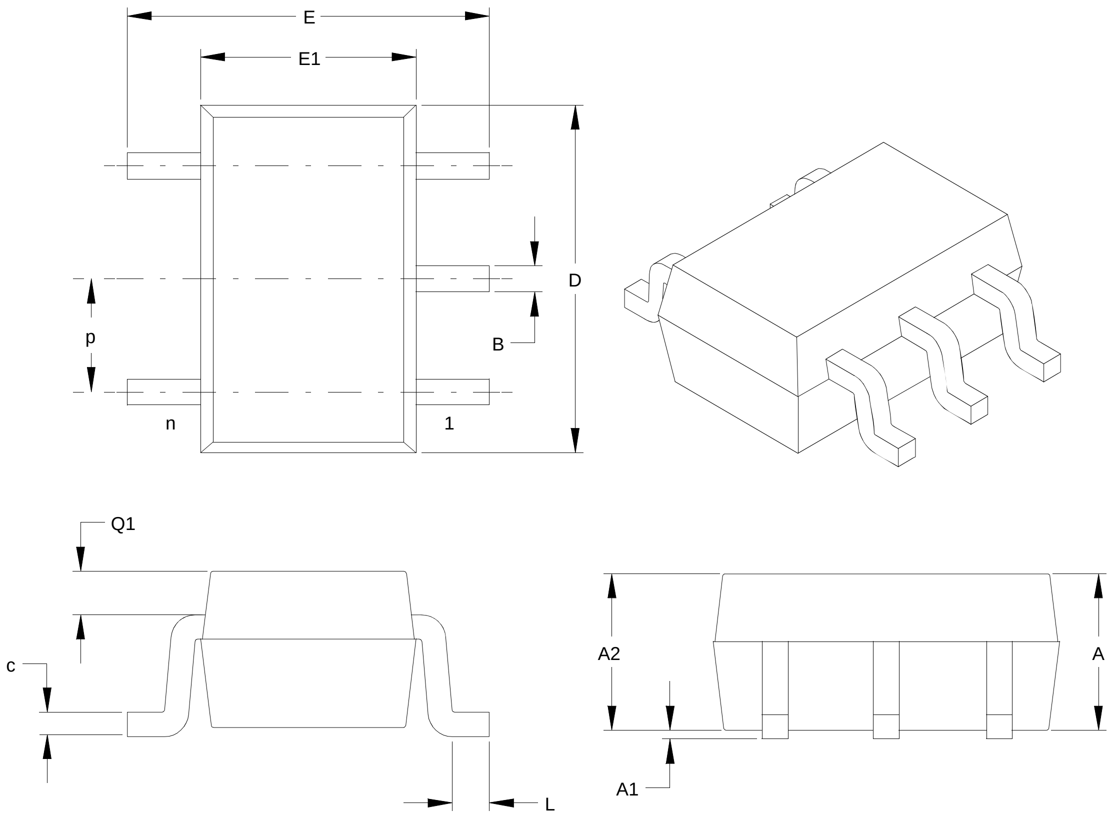
Example:



Legend:	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code
	e3	Pb-free JEDEC designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

5-Lead Plastic Small Outline Transistor (LT) (SC-70)



Units		INCHES			MILLIMETERS*		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		5			5	
Pitch	p		.026 (BSC)			0.65 (BSC)	
Overall Height	A	.031		.043	0.80		1.10
Molded Package Thickness	A2	.031		.039	0.80		1.00
Standoff	A1	.000		.004	0.00		0.10
Overall Width	E	.071		.094	1.80		2.40
Molded Package Width	E1	.045		.053	1.15		1.35
Overall Length	D	.071		.087	1.80		2.20
Foot Length	L	.004		.012	0.10		0.30
Top of Molded Pkg to Lead Shoulder	Q1	.004		.016	0.10		0.40
Lead Thickness	c	.004		.007	0.10		0.18
Lead Width	B	.006		.012	0.15		0.30

***** Controlling Parameter

Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .005" (0.127mm) per side.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.
See ASME Y14.5M

JEITA (EIAJ) Standard: SC-70
Drawing No. C04-061

Revised 07-19-05

NOTES:

APPENDIX A: REVISION HISTORY

Revision B (October 2005)

The following is the list of modifications:

- Added **Section 3.0 “Pin Descriptions”**
- Added the Linear Active Thermistor™ IC trademark
- Removed the 2nd order temperature equation and the temperature coeficient histogram
- Added a reference to AN1001 and corresponding verbiage
- Added Figure 4-2 and corresponding verbiage

Revision A (March 2005)

- Original Release of this Document.

NOTES:

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

PART NO.	–	X	/XX
Device		Temperature Range	Package

Device:	MCP9700T:	Linear Active Thermistor™ IC, Tape and Reel, Pb free
	MCP9701T:	Linear Active Thermistor™ IC, Tape and Reel, Pb free
Temperature Range:	E =	-40°C to +125°C
Package:	LT =	Plastic Small Outline Transistor, 5-lead

Examples:

a) MCP9700T-E/LT: Linear Active Thermistor™ IC, Tape and Reel, -40°C to +125°C, 5LD SC70 package.

a) MCP9701T-E/LT: Linear Active Thermistor™ IC, Tape and Reel, -40°C to +125°C, 5LD SC70 package.

NOTES:

WORLDWIDE SALES AND SERVICE

AMERICAS

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